Lecture 4

Hints to solve Problem 11 page 28 in original form.

How long does it take for a 1 kW heater to raise the temperature of 5 gallons of water by 27^0 F (e.g. from 63^0 to 90^0F)?

Formulation:

1 calorie heat needed to raise 1 gm of water by 1^0 Celsius.

Energy = power x time.

Step# 1: collect formulas needed

$1\ calorie = 4.2\ Joules$

$C/5 = (F - 32)/9$

$t = (Useful\ \ Heat\ \ energy)/power$

$\Delta C = 5/9\Delta F$

- 27^0 Temp difference in F = 15^0 Temp difference in C
- 5 US Gallons= 1.94×10^4 gm water
- Heat energy needed = $15 \times 1.94 \times 10^4 \times 4.2 = 1.223 \times 10^6$ Joules
- time= 1.223×10^3 x Seconds = 20 Minutes

Another Heat energy example:

Food is energy too and we are mostly water!!

What about my 2000 C Diet plan?

Kilocalories not calories: 1C= 1Kc= 10^3 calories

Human with weight 70 kgs eats 2000C/day: How much energy can this supply?

What is the temperature difference that it maintains?

70kgs water = 7x 10^4 gms water

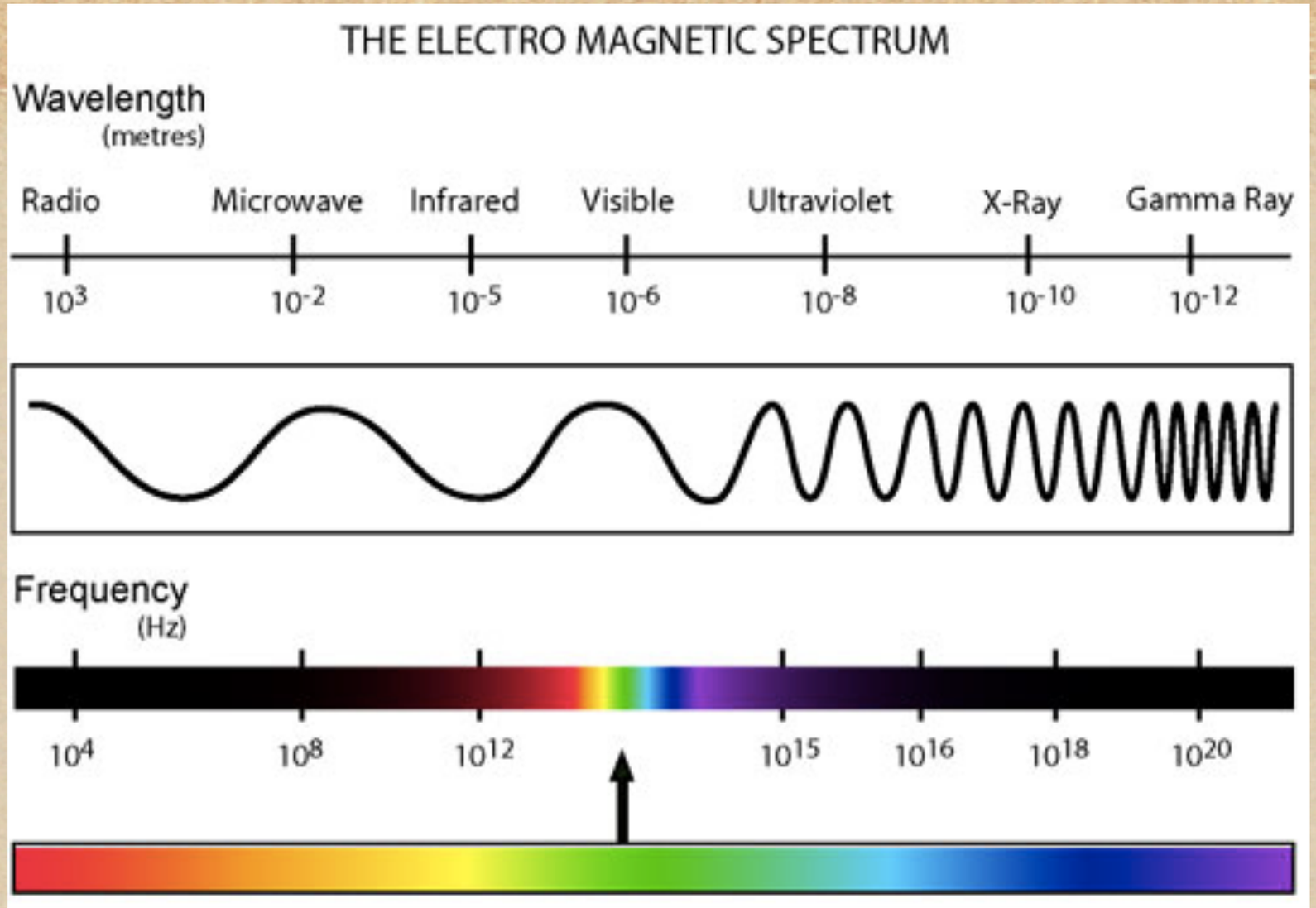
Heat produced = 2x 10^6 calories

$$\Delta T = \frac{2 \times 10^6 \text{ calories}}{7 \times 10^4 \text{ gm}} \sim 29^0 C$$

(Almost) Steady state phenomenon

we lose heat to environment as food supplies further heat.

We are thus heat engines too!



EM spectrum consists of different wavelengths. Colors correspond to different wavelengths.
VIBGYOR of high school science.

Basic theory and formulas:

$$E = \frac{hc}{\lambda}$$

or

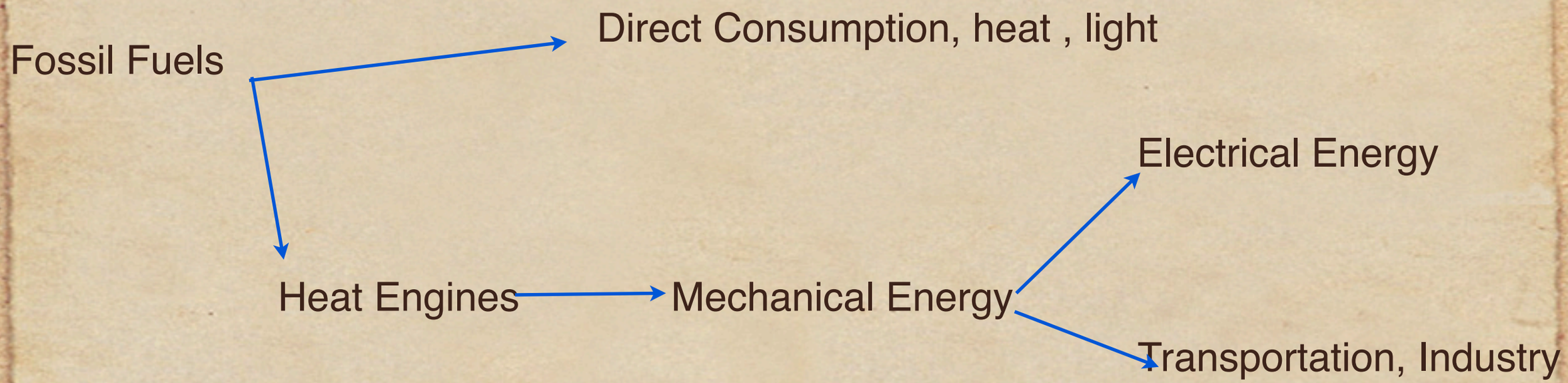
$$E = h\nu$$

E = energy of light (photons)
h = Planck's constant 6.63x 10^{-34} J x sec
c= Velocity of light 3x10^{8} m/sec
λ = wavelength in meters
v = frequency Hertz (=inverse sec)

Example: freq = 10^{13} Hertz energy = 6.63 x10^{-23} J (!!small)

Fossil Fuels

- Petroleum- History and production information
- Petroleum Resources and their depletion: M K Hubbert's thesis
- Petroleum Refining: some facts.
- Natural gas:
- Coal:
- Shale Oil
- Tar Sands



Energy is transported in lossy ways: need to study these mechanisms

Oil - *the uncertain energy source*

The oil and gas we have today was formed in the distant geological past. Microscopic organisms like photo plankton and algae had excessive growth in warm eras in the past. Such warm eras were there 90 to150 million years ago. The dead organisms which sink cause organic debris to be formed. The debris are buried under the sedimentary load brought in by the rivers flowing into the sea. When the debris are buried deep and are subjected, over extended period, to high pressure and temperature, oil is formed. Oil, being lighter than water, moves up along the porous rock till the impervious rock checks the movement and forms a trap for the oil.

Oil is found in such traps. The geological and geophysical data collection and analysis helps explorers in locating such traps in the sub surface. This is a natural process and we can not, in any manner, make it happen. So, whatever was formed in the past and were preserved during the intervening geological upheavals, are the only oil deposits we can discover and produce.

The process takes place in relatively deeper basin areas. There are 500 odd sedimentary basins in the world. About half of them are known to be productive. It is not necessary that every sedimentary basin will be prone to form and preserve oil deposits. The life cycle of oil reservoir formation is of millions of years.

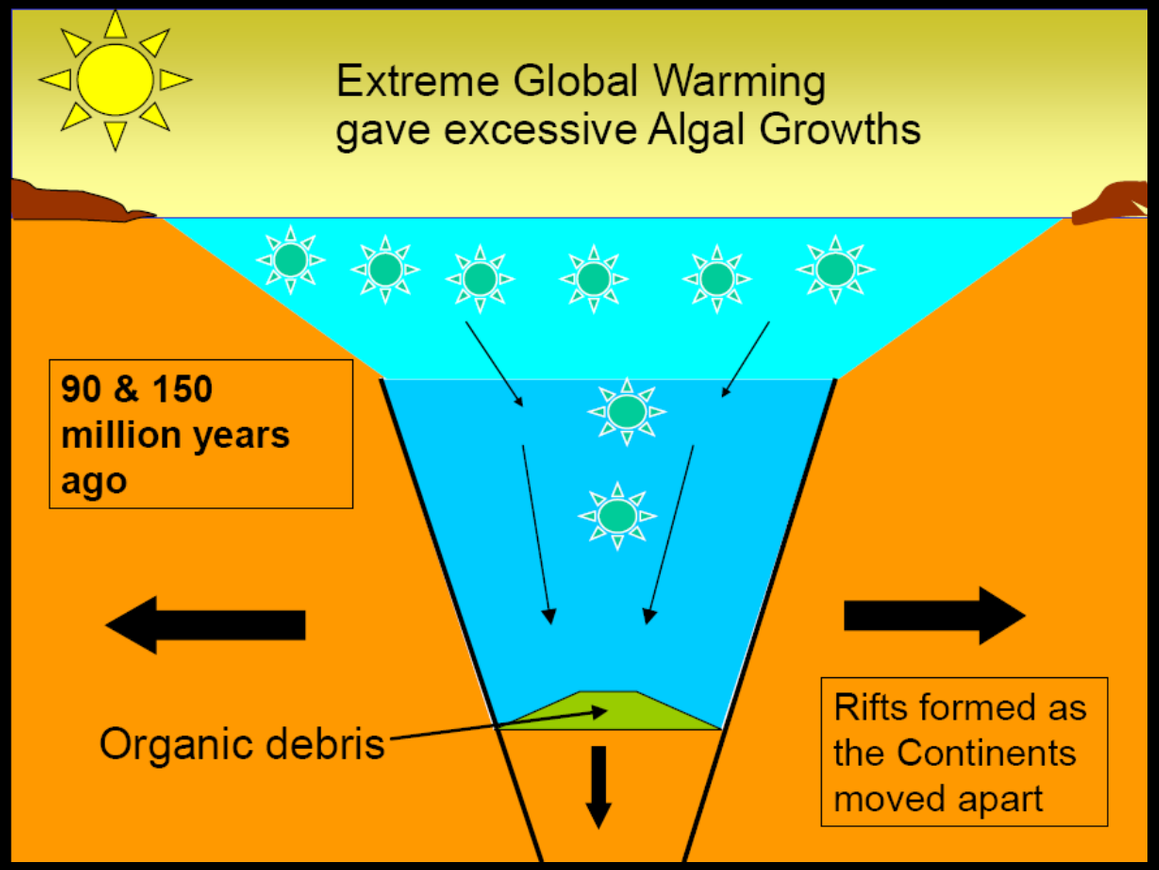
Brief introduction to Fossil Fuels FF
Occurrence to extraction
Overview of Geophysical and other processes

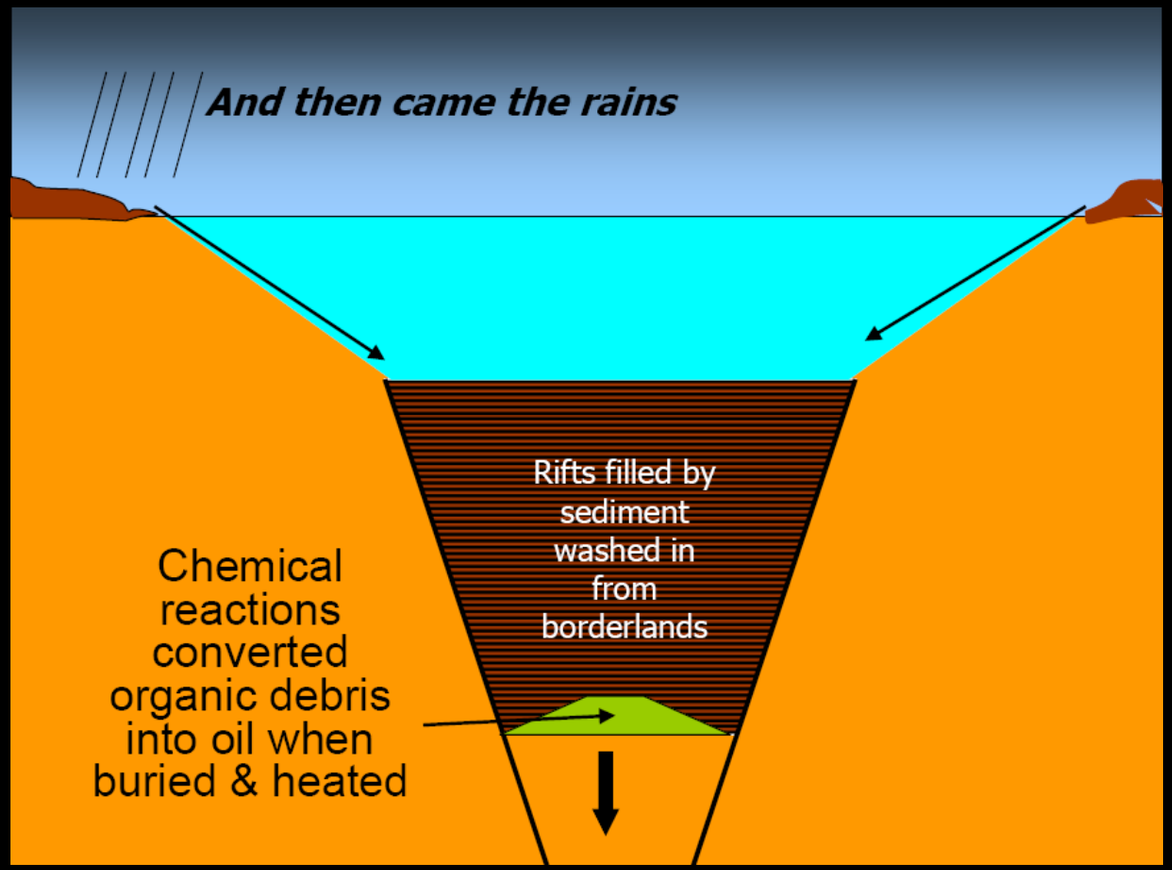
•Most of the continental land was actually ocean floor 100 million years ago. Continents rose and oceans receded where we live today.
•Plant life/organic matter deposited on the then ocean floors 100 million yrs ago.
• Organic matter gets “digested” by bacteria
•Sand deposition and mud create high pressure and Temperature conditions that fluidize + some solid hydrocarbons
•Liquids and gas flow through porus sedimentary rocks: yes rock are very permeable: ask any water diviner
•Natural gas and oil collect in geological traps or are accreted in sandstone
•Use sound echoes to locate oil: differences in rock composition give rise to reflection of waves
•Wildcat drilling (i.e. exploratory drilling) success rate 1 out of 9!
•Establish existence of oil hence estimate “proven reserves”. (reservoir modeling)

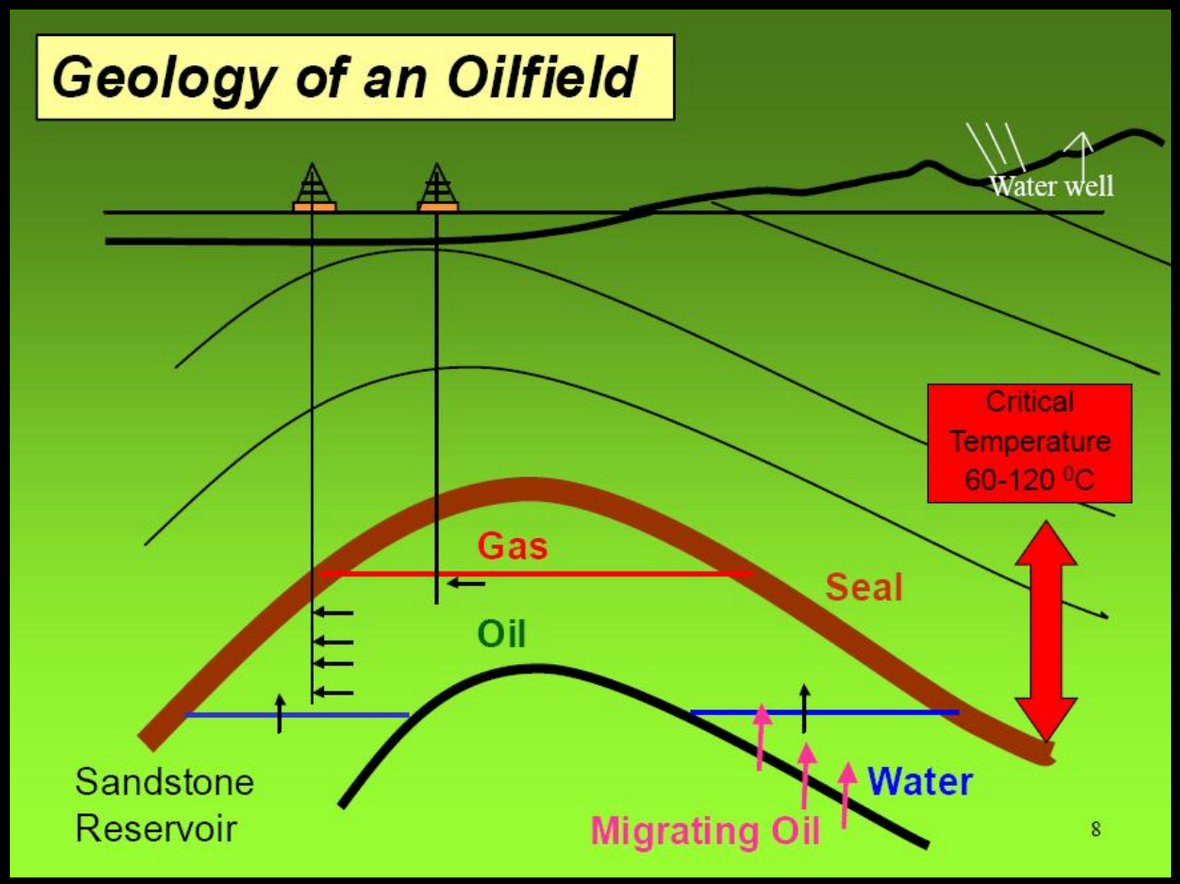
Who is the king of deep oceans?

We often think of sharks and whales as being the kings of the deep oceans. Actually, there are other animals that have established giant kingdoms in the sea...the largest and most impressive kingdoms of all! These animals are various kinds of microscopic creatures....both plant and animal. Most of them would fit on the head of a pin. They are tiny, but there are trillions upon trillions of them. When these creatures die, they sink to the bottom and become part of the shale sediments there. The animals die and rain down on the ocean floor all the time. And since the beginning of life on earth, they have been living their exciting lives in the ocean, dying, sinking to the bottom, and becoming part of the once-living matter that is part of all shale rocks.

Later, when thousands of feet of shale have piled up over millions of years, and the animal bodies are buried very deep (more than two miles down), an amazing thing happens. The heat from deep inside the earth "cooks" the animals, turning their bodies into what we call hydrocarbons.....oil and natural gas.

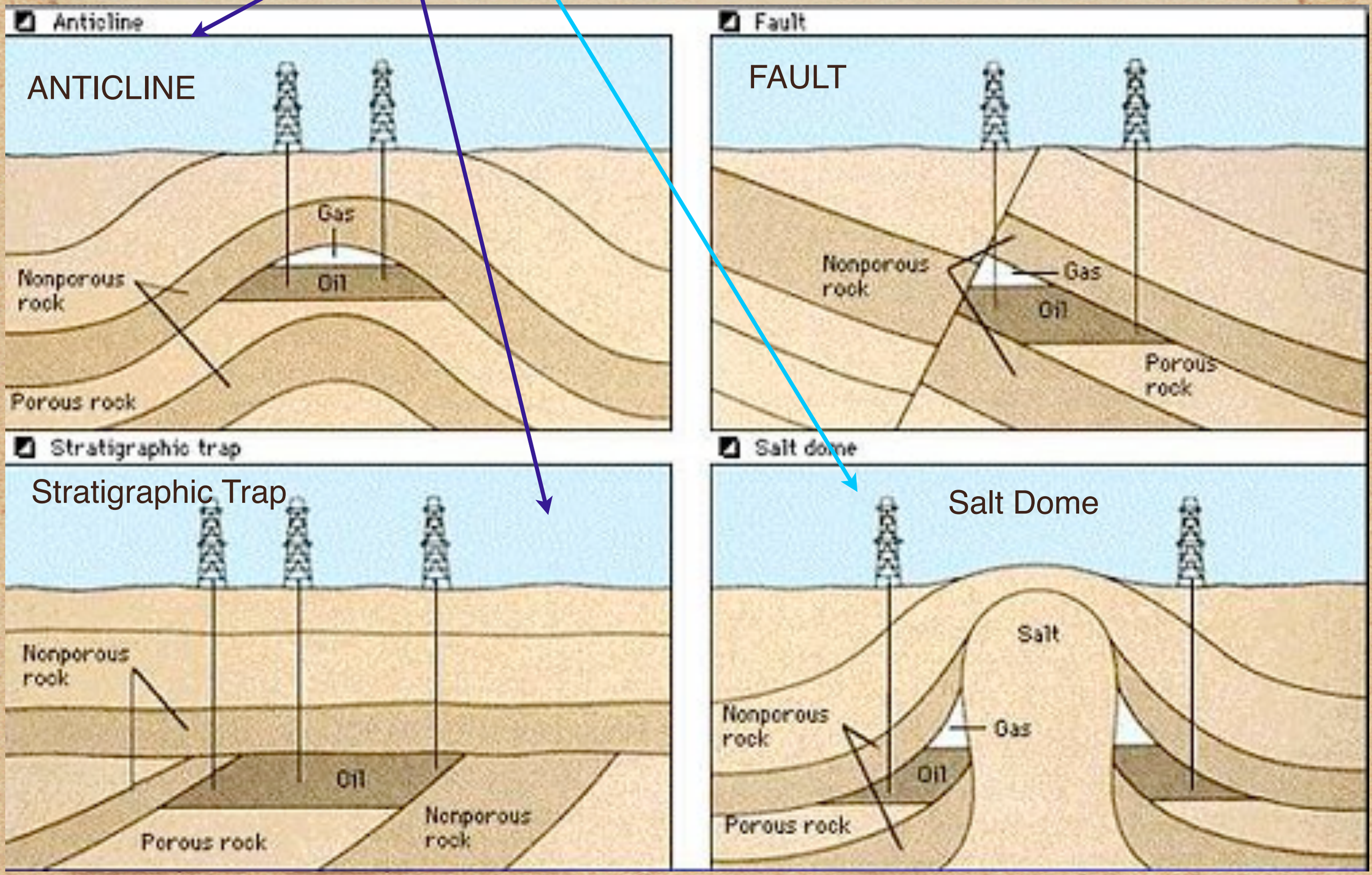






The Formation of Oil and Gas over millions of years under the surface of the earth.

Structural traps



At present we are extracting a small part of available gas
from a given reservoir: lot of physics goes in here

- Normal extraction: 30% max comes out as gas 70% remains
- Secondary recovery: Pump water or gas into surrounding area to get another 15%
- Ternary recovery: Problems are viscosity of oil and surface tension with rocks:

Viscosity is the rate at which things flow. We can manipulate this with high pressure CO_2 or O_2 pumped into reservoir. Occasionally the oil is burnt in part, so as to heat up the remaining oil which will then flow more easily out of the rocks and into our cars. Physics of viscosity is very important here

Surface tension. The oil is trapped in the pores which are clogged up! To get it out, add detergent and then flood with water + polymers (surfactants). Sounds familiar????
Washing machine ideas

Environmental damage due to ternary recovery is often a serious issue!

Cost Issues

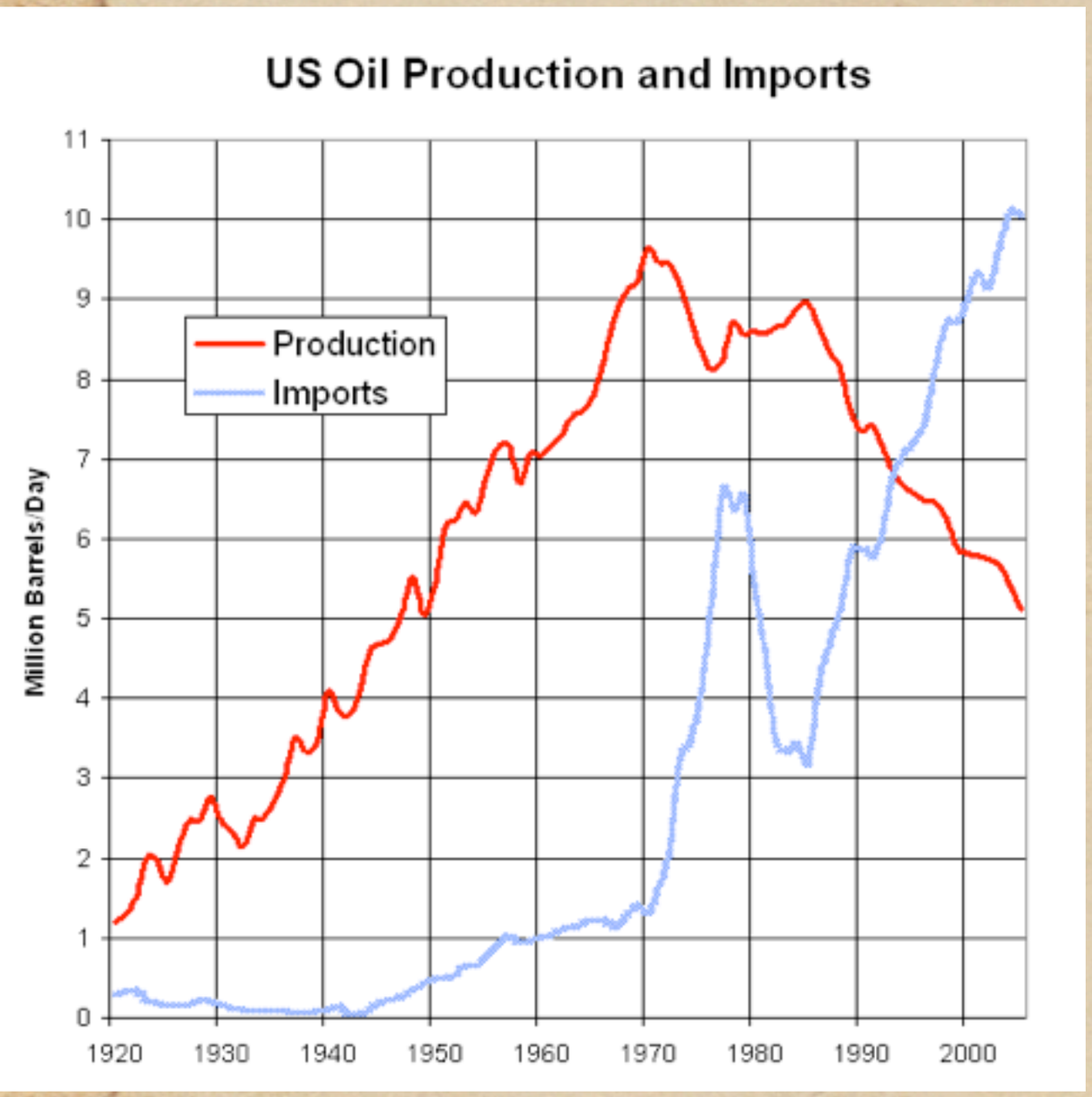
Q: At $4. per gallon, is gasoline cheap or is it not?

A: Compared to all other industrialized nations US and Canada have the cheapest gas by factors of 2 or 3!
In 2002 US taxed $0.40 per gallon compared to $2.80 in Europe and much of Asia.

Saudi and other OPEC countries and Russia have enormous reserves and are producing fast hence the cost is low!!

- USA imports more than 50% (cheaper since OPEC is producing more copiously).
- Low taxation hurts since # cars increases. Deeply political issue in USA more emotion than logic.
- Efficiency has gone up: 2000 /28 mpg 1973/13 mpg
- (1947-1966 my family Oldsmobile gave 3 mpg boosted to 7 mpg by making many changes!! some quite unbelievable feats of “home engineering”

Resource issues: How much do we have left?



M King Hubbert's thesis

Hubbert's estimate for USA in 1955
(ignoring Alaska and off shore)

165×10^9 *barrels*

More current estimates agree with this and add the Alaska / offshore to give Grand total 324 x 10^9 barrels

Already produced 190 x 10^9 barrels: Left with 134x10^9 barrels

World total $\sim 2500 \times 10^9$ *barrels*

World Future estimate $\sim 1790 \times 10^9$ *barrels*

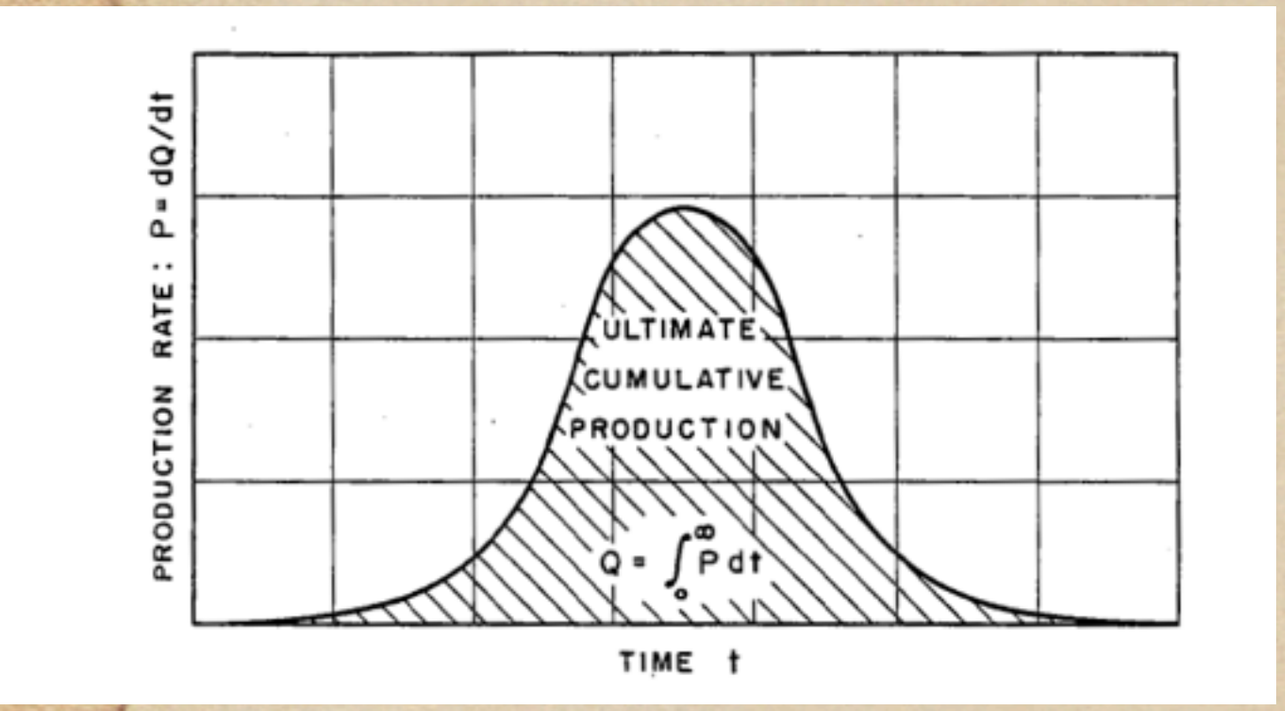
Time left 60 year!!!!

P = production rate

Example a single well may produce 1 Million barrels per day in 1975
changing to .95 in 1976,.... and .75 in 2011.
We will then say that P(t)= 1,.95,..., .75

Actual numbers

P ~ 5.7 Million barrels per day 2003 (USA) ~9 MB/day Saudi: ~70 MB/day world



For any finite resource we may define
Q(t) is the quantity of the produce
upto time "t".

$$Q_\infty = Q(t);\ t \to \infty$$

This represents the grand total of the produce.

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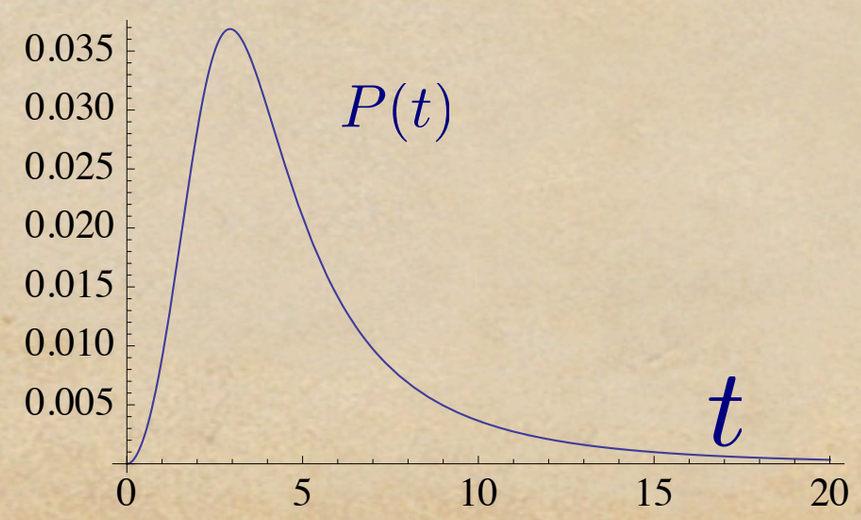

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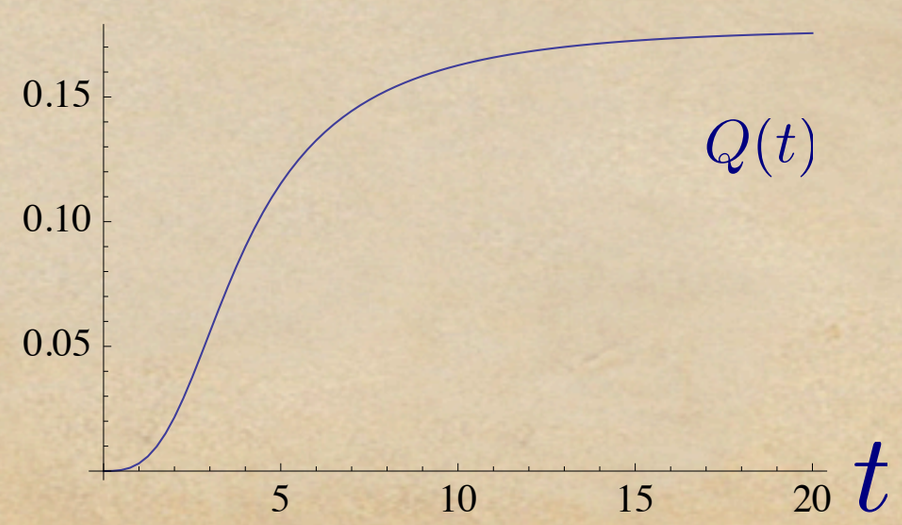

M King Hubbert and FF reserves

NUCLEAR ENERGY AND THE FOSSIL FUELS

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Presented before the
Spring Meeting of the Southern District
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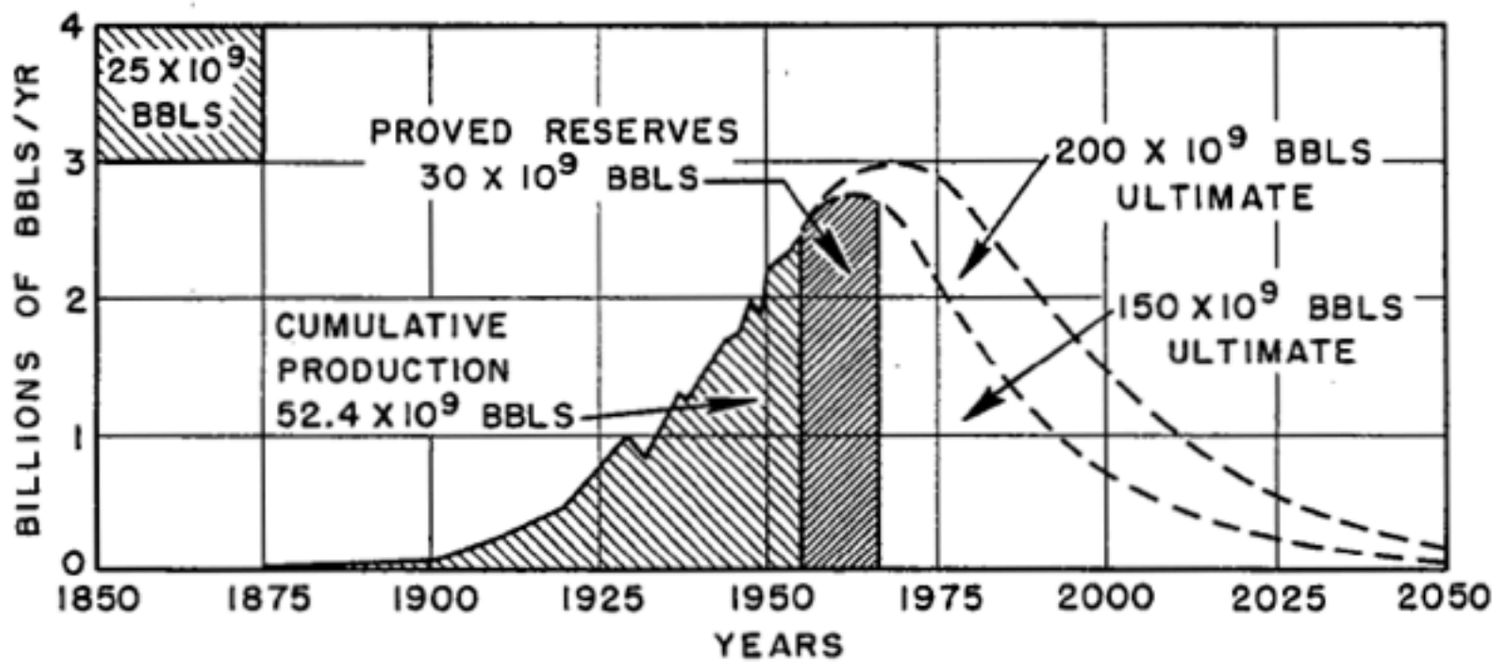

Figure 21 – Ultimate United States crude-oil production based on assumed initial reserves of 150 and 200 billion barrels.

Hubbert also predicted the time lag between discovery of wells and the production peak by about 11 years.